AFRL-RV-PS-
TR-2014-0013

AE9/AP9/SPM RADIATION ENVIRONMENT MODEL: USER'S GUIDE

Christopher Roth

Atmospheric and Environmental Research, Inc.
131 Hartwell Ave.
Lexington, MA 02421

18 February 2014

Technical Report

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

AIR FORCE RESEARCH LABORATORY
Space Vehicles Directorate
3550 Aberdeen Ave SE
AIR FORCE MATERIEL COMMAND
KIRTLAND AIR FORCE BASE, NM 87117-5776

DTIC COPY

NOTICE AND SIGNATURE PAGE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report was cleared for public release by the 377 ABW Public Affairs Office and is available to the general public, including foreign nationals. Copies may be obtained from the Defense Technical Information Center (DTIC) (http://www.dtic.mil).

AFRL-RV-PS-TR-2014-0013 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//SIGNED//	//SIGNED//
Michael J. Starks, DR-III	Edward J. Masterson, Colonel, USAF
Senior Electrical Engineer, RVBXR	Chief, Battlespace Environment Division

This report is published in the interest of scientific and technical information exchange, and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
18-02-2014	Technical Report	11 Jul 2012 to 30 Jul 2013

4. TITLE AND SUBTITLE
AE9/AP9/SPM Radiation Environment Model: User's Guide

5a. CONTRACT NUMBER
FA9453-12-C-0231

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
63401F

6. AUTHOR(S)
Christopher Roth

5d. PROJECT NUMBER
5021

5e. TASK NUMBER
PPM00012019

5f. WORK UNIT NUMBER
EF007946

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Atmospheric and Environmental Research, Inc.
131 Hartwell Ave.
Lexington, MA 02421

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Space Vehicles Directorate
3550 Aberdeen Avenue SE
Kirtland AFB, NM 87117-5776

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/RVBXR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RV-PS-TR-2014-0013

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited. (377ABW-2012-1280 dtd 25 Sep 2012)

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This document is the user's guide for the AE9/AP9/SPM radiation environment model software. AE9/AP9/SPM is a climatological specification model for trapped energetic particles and plasma in the near-Earth environment. The report provides instructions for model installation and operation of the model through both the Command-Line and Graphical User interfaces. Detailed listings of model options are included plus instructions on how to obtain various desired outputs including flux, fluence and dose, and statistics on these quantities.

15. SUBJECT TERMS
AE9/AP9/SPM, radiation belt model, space plasma model, user's guide

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Dr. Michael Starks
Unclassified	Unclassified	Unclassified	Unlimited	44	**19b. TELEPHONE NUMBER** *(include area code)*

This page is intentionally left blank.

Approved for public release; distribution is unlimited.

Table of Contents

This page is intentionally left blank.

AE9/AP9/SPM Radiation Environment Model

User's Guide

Windows and Linux Platforms

Approved for public release; distribution is unlimited.

The AE9/AP9/SPM model was developed by the National Reconnaissance Office and the Air Force Research Laboratory in partnership with MIT Lincoln Laboratory, Aerospace Corporation, Boston College Institute for Scientific Research, Atmospheric and Environmental Research, Incorporated, and Los Alamos National Laboratory.

AE9/AP9 development team: Gregory Ginet[1] (PI), T. Paul O'Brien[2] (PI), Dave Byers[3], Michael Starks[4], Stuart Huston[5,6], Wm. Robert Johnston[4], Tim Guild[2], Christopher Roth[6], Paul Whelan[6], Rick Quinn[6], Reiner Friedel[7], Chad Lindstrom[4], Dan Madden[5], Steve Morley[7], and Yi-Jiun Su[4].

Information on AE9/AP9 may be found on line at the NASA SET Radiation Model User Forum (http://lws-set.gsfc.nasa.gov/radiation_model_user_forum.html).

To contact the AE9/AP9 team, email AFRL.RVBXR.AE9.AP9.Org.Mbx@kirtland.af.mil.

V1.05.001 release: August 2013

[1] MIT Lincoln Laboratory
[2] Aerospace Corporation
[3] National Reconnaissance Office
[4] Air Force Research Laboratory, Space Vehicles Directorate
[5] Boston College Institute for Scientific Research
[6] Atmospheric and Environmental Research, Incorporated
[7] Los Alamos National Laboratory

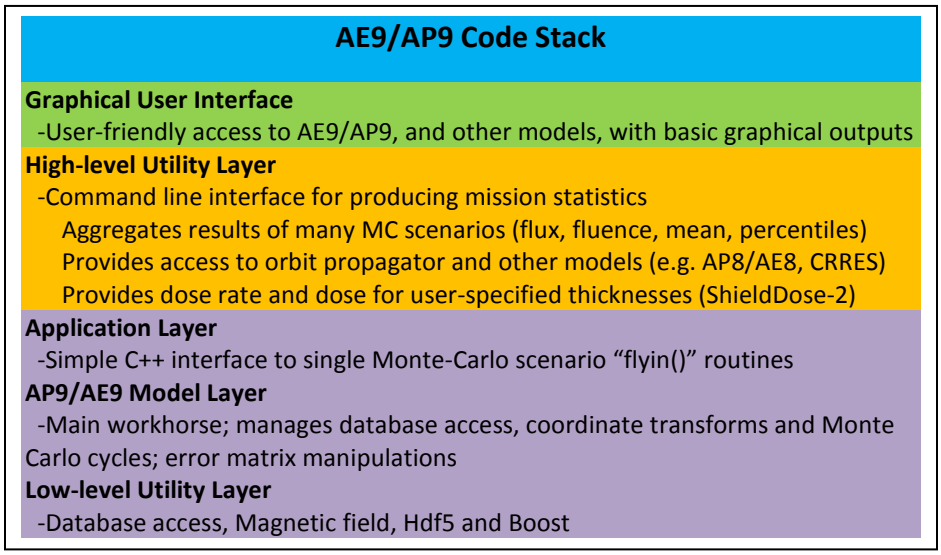
Approved for public release; distribution is unlimited.

AE9/AP9/SPM Model Program Overview

This delivery contains all files needed to install and execute the C++-based AE9/AP9/SPM Radiation Environment model, using a command-line program execution, or through a graphical user interface (GUI).

The Command-Line program '`CmdLineAe9Ap9.exe`' reads model parameters and orbit specifications from user-constructed input files and produces the requested set of files containing flux and fluence calculation results. Dose calculation results are also available.

The GUI program '`testAe9Ap9Gui.exe`' provides a graphical user interface to specify an orbital path and various model parameters in a user-friendly format. The GUI program executes the `CmdLineAe9Ap9` program using the input files automatically generated according to the user's selections in the interface. Basic 2D plots of the model results may also be produced.



In addition to this User's Guide, there are several other files of information provided in this distribution. The '`Readme_CmdLineAe9Ap9`' file provides a complete list of various database and supporting files used in the model. Several annotated samples of command-line input files are also supplied:

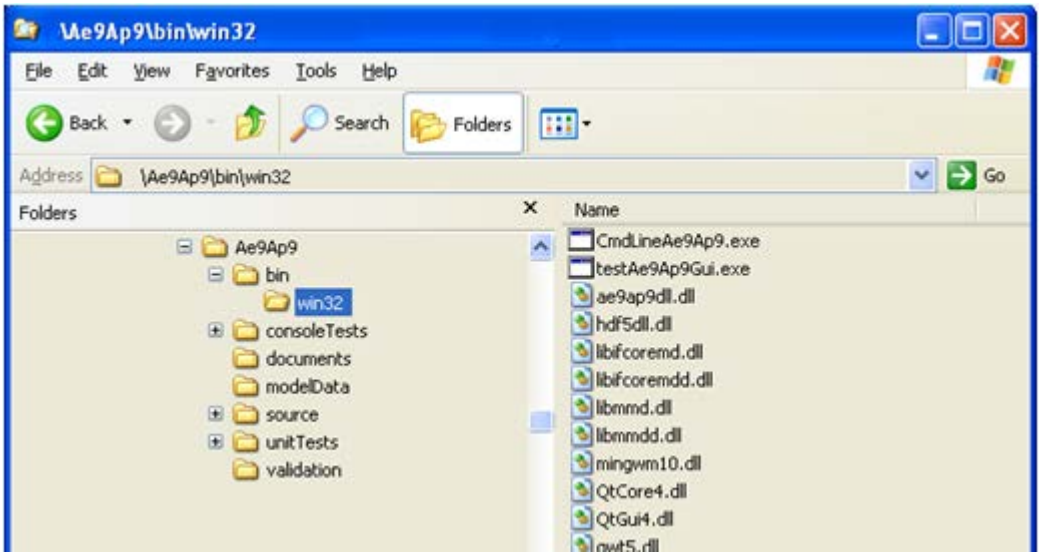
- `Ae9Ap9CmdlineInputSample_V1_0.txt`
- `Ae9Ap9CmdlineOrbitSample.txt`
- `Ae8Ap8CrresCmdlineInputSample_V1_0.txt`
- `CammiceCmdlineInputSample_V1_0.txt`

Additional subdirectories contain several test files (both input and output) for verifying proper model installation and operation.

Model Installation

Version 1.00.003 of the AE9/AP9 Radiation Environment model is distributed as a zipfile, '`Ae9Ap9_version_1.00.003.zip`', containing Windows release-mode binaries and libraries, model databases, sample input and output files and supporting documentation files. A separate source distribution may also be provided, upon request, for generating Windows debug-mode binaries, or for building the binaries on Linux platforms.

For a Windows installation, simply unzip the distribution file in the desired directory location. The directory structure will be as shown below:



For a Linux-based installation, unzip the source distribution file in the desired location, then refer to the detailed instructions in the '`Build_Instructions_for_AE9AP9.pdf`' file in the '`Ae9Ap9/documents`' directory.

Installation Testing

Open a command line window, navigate to the directory containing the binary executables (ie Ae9Ap9/bin/win32), enter the command:

```
CmdLineAe9Ap9 –i ../../consoleTests/short.txt
```

The resulting output files will be written in this same directory. Verify that the number of files generated, and respective file contents match that of the "`shortOutput`"-prefixed files located in the '`../../consoleTests/expectedTestOutputs`' directory. Other test input files are also available in this '`consoleTests`' directory, and their corresponding output files in the '`expectedTestOutputs`' subdirectory.

Much more information regarding the CmdLineAe9Ap9 program is provided in the next section of this document.

To start the GUI program, enter the command (or double-click the icon for):

```
testAe9Ap9Gui.exe
```

A detailed description of the GUI program follows in a later section of this document.

Command-Line Program

The CmdLineAe9Ap9 program is a lightweight client application for running the 'AE9/AP9' and 'Plasma' models at time-tagged orbital positions. The requested model calculation results are written to comma-separated value (CSV) format text files. Other 'legacy' radiation belt models, 'AE8', 'AP8', 'CRRESELE', 'CRRESPRO' and 'CAMMICE/MICS', are also available within this same application.

The command-line utility takes input settings from an external file, which is passed to it using the input parameter '`-i <filename>`'. This feature permits the CmdLineAe9Ap9 program to be used in "batch" mode or within a script, and/or distributing large modeling tasks across multiple processors and servers. Very long model runs can easily be broken up by time or species, and the results merged using user-supplied post-processing scripts.

The format of the input file used to drive the CmdLineAe9Ap9 program, as well as the detailed model settings specified within it, are described below. A working sample input file, '`Ae9Ap9CmdLineInputSample_V1_0.txt`' is provided in the 'Ae9Ap9/bin/win32' directory. This annotated sample file contains complete descriptions of all available input parameters to the model and all of the allowed values for each.

Input File Construction

The basic format of the input file is 'keyword/value' pairs on each line: the parameter keyword name, followed by a colon and then the value or values for the parameter. Keywords and string values are *not* case-sensitive. Lines beginning with a '#' symbol are treated as comments, and are therefore ignored by the program.

CmdLineAe9Ap9 input file settings can be logically grouped into the following categories:

Basic Model Inputs	– core model parameters, required for any model run
Aggregation Inputs	– optional settings for combining complex output results
Dose Calculation Inputs	– optional settings to drive the ShieldDose2 dose calculations
Orbit Propagator Inputs	– optional settings for generating orbit ephemeris

Input file settings for each of these categories are described in the following tables. Descriptions of the parameters used for the legacy models may be found in the Appendices.

Basic Model Inputs

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
ModelType	AE9, AP9, PLASMA Legacy models*: AE8, AP8, CRRESELE, CRRESPRO, CAMMICE	Required	none	Type of model to be run (requires corresponding database file specified in ModelDB parameter) *See Appendices A and B for Legacy model parameters
ModelDB	AE9V10_runtime_tables.mat AP9V10_runtime_tables.mat SPMEV10_runtime_tables.mat SPMHV10_runtime_tables.mat SPMHEV10_runtime_tables.mat SPMOV10_runtime_tables.mat	Required	none	Database file used to drive the model, corresponding to the selected ModelType). Must include path to file (absolute, or relative to CmdLineAe9Ap9 location). For PLASMA: specify the appropriate 'SPM*' species file: 'E' (electrons), 'H', 'HE' (He), 'O';
OrbitFile	valid path and file name of ephemeris file	Required	none	The path and file name of a valid file containing sets of time and orbit position coordinates (in CSV format and in the coordinate system specified by the CoordSys parameter). Alternatively, when using orbit propagation inputs, this parameter specifies the path and file name of the ephemeris information to be *written*.
DirFile	valid path and file name of direction file	Optional	Omni-directional flux	The path and file name of a valid file containing ('CoordSys') direction vectors associated with the positions in the specified OrbitFile ('CoordSys' must be one of the *Cartesian* coordinate systems for proper application).
CoordSys	GEO, GEI, GDZ, GSM, GSE, SM, MAG, SPH, RLL	Required	none	Coordinate system of position values in the specified (input) OrbitFile (and optional DirFile) files See the 'Supported Coordinate Systems' table on page 10.

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
FluxType	1PtDiff, 2PtDiff*, Integral	Required	none	Type of flux to be computed. *Two-point differential requires both 'Energies' and 'Energies2' parameter values
Energies	AE9: 0.04 – 10.0 (MeV) AP9: 0.1 – 400.0 (MeV) Plasma/electrons: 0.001 – 0.040 (MeV) Plasma/ions: 0.00115 – 0.1643 (MeV)	Required	none	Comma-separated list of energy levels, in MeV, at which flux values are to be computed, at each time step. Energy values are restricted to their model-specific ranges.
Energies2	(same as 'Energies')	Optional	none	Used only when 'FluxType' = '2PtDiff'. A comma-separated list of energy levels that define the end of the energy ranges, between which fluxes are computed. The 'Energies' parameter defines the start of each range. These two parameter lists must contain the same number of energy levels.
OutFile	valid path and file name	Required	none	A path and file name "prefix" that will be used when generating the output file(s); the naming of these files is based on this prefix and the various model output and aggregation parameters also specified in the input file. **Any previously generated output files with this same "prefix" will be *overwritten*.**
MagfieldDB	*<path>*/igrfDB.h5	Required	none	Magnetic field model's database file, including path
KPhiNNetDB	*<path>*/fastPhi_net.mat	Required	none	K/Phi coordinate neural network database file, including path

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
KHminNNetDB	*<path>*/fast_hmin_net.mat	Required	none	K/Hmin coordinate neural network database file, including path
FluxOut	mean percentile,## perturbed,### montecarlo,###*	Required	none	Flux data to be output. This parameter may appear multiple times. The 'mean' is a simple mean value. The 'percentile' number may be in the range 1-99. The 'perturbed' mean and/or 'montecarlo' scenario identification numbers may be in the range 1-999. See the full explanation of these different types of modes in the section following this table. *montecarlo is not applicable for 'Plasma' model
FlueOut	mean percentile perturbed montecarlo*	Optional	none	Fluence data to be output. This parameter may also appear multiple times. No percentile or scenario identification numbers are specified here; the corresponding 'FluxOut' numbers will be used. *montecarlo is not applicable for 'Plasma' model
DoseOut*	mean percentile perturbed montecarlo	Optional	none	Dose rate data to be output. May appear multiple times. No percentile or scenario identification numbers should be used here, as the ones from the corresponding FluxOut values will be used. *Requires additional Dose Calculation input parameters, in a following section. Not applicable for Plasma model.

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
CDoseOut*	mean percentile perturbed montecarlo	Optional	none	Cumulative dose data to be output. May appear multiple times. No percentile or scenario identification numbers should be used here, as the ones from the corresponding FluxOut values will be used. *Requires additional Dose Calculation input parameters, in a following section. Not applicable for Plasma model.
Epoch	Date/time (in Modified Julian date* form)	Optional	First ephemeris point time	Specify an alternate time as the epoch value for a model run. This permits model runs with long ephemeris periods to be broken up into multiple runs (over time) when performing "Monte Carlo" and/or "Perturbed Mean" scenario calculations. See the flux data mode explanation below. *See Appendix C for information on Modified Julian Dates.

Supported Coordinate Systems

CoordSys	Full Coordinate System Name	Coordinate Values(units)
GEI	Geocentric Earth Inertial or Earth-Centered Inertial (ECI)	X(Re), Y(Re), Z(Re)
GEO	Geocentric Cartesian	X(Re), Y(Re), Z(Re)
GDZ	Geodetic	alt(km), lat(deg), lon(deg)
GSM	Geocentric Solar Magnetospheric	X(Re), Y(Re), Z(Re)
GSE	Geocentric Solar Ecliptic	X(Re), Y(Re), Z(Re)
SM	Solar Magnetic	X(Re), Y(Re), Z(Re)
MAG	Magnetic	X(Re), Y(Re), Z(Re)
SPH	Spherical	radius(Re), colatitude(deg), lon(deg)
RLL	Radius, Latitude, Longitude	radius(Re), lat(deg), lon(deg)
1 Re = 6371.2 km		
See [Bhavnani and Vancour, 1991] for full descriptions of these coordinate systems.		

Approved for public release; distribution is unlimited.

Details about the Flux Data Modes

The 'FluxOut', and associated parameters, is used specify the various types of flux data to be returned by the model. The 'mean' and 'percentile' modes capture the statistical behavior of the data upon which the model was built. The 'perturbed' mode adds the uncertainties in the mean flux maps that are due to measurement and gap-filling errors. The 'montecarlo' mode contains all these uncertainties of the 'perturbed' mode, then adds an estimate of the dynamic variations due to space weather processes. The multiple "scenarios" of the latter two modes are specified with scenario identification numbers (used to produce a random number seed), each producing a different flux profile for every orbit, bounded by the variances due to measurement error and space weather. These variations represent the range associated with space weather on multiple timescales and span the variability observed throughout a solar cycle; however, the solar cycle phase is not reproduced. This scenario "seed" number enables these results of the model calculations to be fully reproducible, provided that the same ephemeris information and 'epoch' time reference are used. Unless otherwise specified, the 'epoch' time defaults to the first time of the ephemeris information.

The 'Epoch' parameter is vital when breaking up a long time series 'perturbed' or 'montecarlo'-mode simulation into separate model runs. Each time segment can be run separately and then manually combined afterwards *if the same 'Epoch' value is specified for all time segment model runs.*

By aggregating the results of a large number of mission scenarios (each with a different seed number), the percentile flux levels of any quantity derivable from the flux spectrum, e.g. fluence (time integrated flux) or total dose, may be calculated in terms of probabilities of occurrence during the course of the mission or on other timescales.

Much more information about the model may be found in [Ginet, et al, 2013].

Approved for public release; distribution is unlimited.

Aggregation Inputs

Model aggregation values are available when the 'FluxOut/perturbed,###' and/or 'FluxOut/montecarlo,###' parameters are specified, but are statistically meaningful only when at least five scenarios are used. Each of these parameters may appear multiple times in order to specify the desired aggregate output files. 'MonteCarlo' aggregations are not applicable to 'Plasma' model outputs.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
PMAggX	mean median percentile,##	Optional	none	Aggregate flux results across 'perturbed mean' scenarios defined in FluxOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
PMAggF	mean median percentile,##	Optional	none	Aggregate fluence results across 'perturbed mean' scenarios defined in FlueOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
PMAggD	mean median percentile,##	Optional	none	Aggregate dose rate results across 'perturbed mean' scenarios defined in DoseOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
PMAggCD	mean median percentile,##	Optional	none	Aggregate cumulative dose results across 'perturbed mean' scenarios defined in CDoseOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
MCAggX*	mean median percentile,##	Optional	none	Aggregate flux results across 'monte carlo' scenarios defined in FluxOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep. *monte carlo aggregations are not applicable for 'Plasma' model

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
MCAggF	mean median percentile,##	Optional	none	Aggregate fluence results across 'monte carlo' scenarios defined in FlueOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
MCAggD	mean median percentile,##	Optional	none	Aggregate dose rate results across 'monte carlo' scenarios defined in DoseOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.
MCAggCD	mean median percentile,##	Optional	none	Aggregate cumulative dose results across 'monte carlo' scenarios defined in CDoseOut settings. Computes the mean, median or percentile ## (1..99) across the scenarios at each timestep.

Dose Calculation Inputs

These parameters, used as inputs to the "ShieldDose2" model, are required when 'DoseOut' and/or 'CDoseOut' parameters are specified. Dose calculations are not applicable for the 'Plasma' model. More details about these ShieldDose2 model parameters may be found in [Seltzer, 1994]. Note that the ShieldDose2 "Bremsstrahlung" data tables being used by the CmdLineAe9Ap9 application have been updated to correct an error present in the original SHIELDOSE2 publication. In the 'elbrbas2.dat' file, with the exception of the *Al* detector targets, the *finite slab* and *semi-infinite slab* data tables had been switched [Heynderickx, 2013].

Parameter Keyword Name	Allowed Values	Required for Dose calc.	Default Value	Description
DoseDepths	0.111 – 111.1 (mm) 4.374 – 4374 (mils) 0.03 – 30.0 (g/cm^2)	Required	none	Comma-separated list of Aluminum shielding thickness depths, in units specified by the DoseDepthU parameter. Depth values are recommended to be limited to these ranges specified; validity of results for depths outside these ranges is uncertain.

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required for Dose calc.	Default Value	Description
DoseDepthU	millimeters mils gpercm2	Optional	millimeters	Units of Aluminum shielding thickness depth
DoseDetGeom	spherical finiteslab semiinfiniteslab	Optional	spherical	Geometry of Aluminum shielding in front of (or around) detector - ½ dose at center of solid aluminum sphere - dose at transmission surface of finite aluminum slab - dose in semi-infinite aluminum medium
DoseDetType	Aluminum, graphite, silicon, air, bone, calcium, gallium, lithium, glass, tissue, water	Optional	aluminum	Detector material type
DoseAttnMd	none nuclearinteractions nuclearandneutrons	Optional	"none"	Nuclear attenuation mode for dose calculations -no nuclear attenuation -nuclear attenuation, but neglecting neutron energy transport -nuclear attenuation including neutron energy transport
DoseIntrvl	time interval (days)	Optional	0.0* (=each timestep)	Integration interval (in days) over which to calculate dose rate. If only the total dose information *for the entire time period* is desired, specify a very large number (ie '9999') *Note that dose computations are slow; use of a longer interval can significantly improve overall model performance. It is also recommended that the interval be set to an exact multiple of the orbit cadence. Calculations assume the ephemeris time steps are constant.

Approved for public release; distribution is unlimited.

Orbiter Propagator Inputs

When the appropriate set of these orbit parameters is specified, the generated ephemeris information is written to the file specified by the 'OrbitFile' parameter (in the *Basic Model Inputs* group), **replacing the ephemeris file if it already exists.** However, be aware that the ephemeris time and position and information (supplied or generated) is always included in all model output files.

Parameter Keyword Name	Allowed Values	Usage Coordination	Default Value	Description
OrbTLE	Valid path and file name of Two Line Elements (TLE) file	Conditionally Required*	none	Path and filename of the TLE file used to generate an orbit file, using 'SatEph' or 'SGP4' propagators. *Orbit propagation requires that either this field or OrbElmTim must be set.
OrbStart	Date/time*	Always Required	none	Start date and time, in modified Julian date (MJD*) form, of orbit positions to generate. *See Appendix C for information on Modified Julian Dates.
OrbEnd	Date/time	Always Required	none	End date and time, in MJD format, of orbit positions to generate
OrbStep	>0	Always Required	none	Time interval (in seconds) between orbit positions. Recommended values, according to general orbit type: LEO: 10 sec; MEO: 300 sec; HEO: 60 sec; GEO: 3600 sec.
OrbPropType	SGP4, SatEph, Kepler	Always Required	none	Type of orbit propagator to use for generating the orbit ephemeris information. 'SGP4' is a commonly-used orbit propagator. 'SatEph' is another name for the Lokangle propagator, developed and used by AFRL for decades. 'Kepler' is a very basic orbit propagator with optional J2 perturbation effects.

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Usage Coordination	Default Value	Description
OrbElmTim	Date/time	Conditionally Required*	none	Time, in Modified Julian day+ form, associated with the specified orbital element values *Orbit propagation requires that either this field or 'OrbTLE' must be specified. +See Appendix C for information on Modified Julian Dates.
OrbMode	Standard, Improved	Required for 'SGP4'	Standard	Run mode for 'SGP4' propagator
OrbDatum	72Old, 72, 84	Required for 'SGP4'	none	WGS Datum constants to use. World Geodetic System spheroidal definition of the Earth.
OrbElemType	'solar', 'mean', 'classical', 'geosync', or 'rv'	Required for 'Kepler'	none	Type of orbital element value inputs to be used with the 'Kepler' propagator (No TLE files). The necessary parameters for the different types of elements are annotated by their name in the 'Required' column here.
OrbUseJ2	true, false	Required for 'Kepler'	false	Use J2 perturbations in Kepler propagation algorithm
OrbIncl*	0 – 180 (degrees)	'mean' or 'solar' or 'classical'	none	Orbital inclination (degrees) *Orbital element parameters, here and below, that are marked with 'mean' may be used with any of the three propagators. All others may only be used with the 'Kepler' propagator.
OrbArgPer	0 – 360 (degrees)	'mean'	none	Argument of perigee (degrees)
OrbMeanAn	0 – 360 (degrees)	'mean'	none	Mean anomaly (degrees)

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Usage Coordination	Default Value	Description
Orb1stDer	-10 – +10	'mean'	none	First derivative of mean motion (rev/day^2)
OrbEccen	0.0 – 1.0	'mean' or 'classical'	none	Eccentricity (unitless)
OrbRAAsNd	0.0 – 360.0 (degrees)	'mean' or 'classical'	none	Right ascension of ascending node (degrees), also known as the *celestial* longitude of the ascending node.
OrbMeanMo	>0.0 – 30.0	'mean'	none	Orbital mean motion (revolutions/day)
Orb2ndDer	-1 – +1	'mean'	none	Second derivative of mean motion (rev/day^3)
OrbBStar	-1 – +1	'mean'	none	Ballistic coefficient
OrbAltPer	>0 – ~50xRe	'solar'	none	Altitude of perigee (km)
OrbAltApo	>0 – ~50xRe	'solar'	none	Altitude of apogee (km)
OrbLocTimeApo	0 – 24 (hours)	'solar'	none	Local time of apogee (hours)
OrbLocTimeMaxIncl	0 – 24 (hours)	'solar'	none	Local time of maximum inclination [ie, max latitude] (hours)
OrbSmjAxis	>0 – ~50xRe	'classical'	none	Semi-major axis (Re)
OrbTimPerig	Date/time	'classical'	none	Time of perigee, in MJD form
OrbPosXyz	|<125,000km|	'rv'	none	Position (X,Y,Z in GEI [km]) at orbital element time
OrbVelXyz	|<50km/sec|	'rv'	none	Velocity (X,Y,Z in GEI [km/s]) at orbital element time
OrbGeoLon	0 – 360 (degrees)	'geosync'	none	Geographic longitude (deg) at orbital element time

Approved for public release; distribution is unlimited.

Two-Line Element Files

Two-Line Element (TLE) is a standard NORAD data format used to convey sets of orbital element values that describe the orbital motion of Earth-orbiting satellites. Current and archived TLE data for many satellites may be obtained from various online sources, such as http://www.celestrak.com.

The orbit propagator routines, such as 'SGP4' and 'SatEph', can use TLE files that contain multiple entries of TLE (in chronological order) for a single satellite. The 'SatEph' routines perform interpolation between adjacent TLE entries for smooth ephemeris results.

The standard NORAD format for the Two-Line Elements is shown in the table below:

TLE Line 1		TLE Line 2	
Column	Description	Column	Description
01	Line Number of Element Data	01	Line Number of Element Data
03-07	Satellite Number	03-07	Satellite Number
08	Classification (U=Unclassified)	09-16	Inclination [Degrees]
10-11	International Designator (Last two digits of launch year)	18-25	Right Ascension of the Ascending Node [Degrees]
12-14	International Designator (Launch number of the year)	27-33	Eccentricity (decimal point assumed)
15-17	International Designator (Piece of the launch)	35-42	Argument of Perigee [Degrees]
19-20	Epoch Year (Last two digits of year)	44-51	Mean Anomaly [Degrees]
21-32	Epoch (Day of the year and fractional portion of the day)	53-63	Mean Motion [Revs per day]
34-43	First Time Derivative of the Mean Motion	64-68	Revolution number at epoch [Revs]
45-52	Second Time Derivative of Mean Motion (decimal point assumed)	69	Checksum (Modulo 10)
54-61	BSTAR drag term (decimal point assumed)		
63	Ephemeris type		
65-68	Element number		
69	Checksum (Modulo 10)		

Example Two-Line Element set (32765 = C/NOFS satellite):

```
1 32765U 08017A   11150.09749074 +.00010799 +00000-0 +47888-3 0 0797
2 32765 013.0015 105.8044 0295409 031.4522 330.3172 14.8643027916917
```

Some potentially helpful online resources for understanding the orbital element definitions:

http://www.braeunig.us/space/orbmech.htm
http://www.amsat.org/amsat/keps/kepmodel.html
http://marine.rutgers.edu/mrs/education/class/paul/orbits.html
http://en.wikipedia.org/wiki/Orbital_elements

Orbit Ephemeris File Description

The ephemeris file, required for performing the model calculations, can be generated by one of the available orbit propagators, or can be supplied by the user (but must be in the expected format). The user-supplied (input) or generated (output) ephemeris file name is specified with the required 'OrbitFile' parameter.

The comma-separated value (CVS)-formatted ephemeris file may contain any number of header lines (comments), designed with a '#' in the first column. The data values are expected in four columns: date/time (in Modified Julian day+fraction form, see Appendix C), and three coordinates of one of the supported coordinate systems (in the specified order and appropriate units). The coordinate system of the user-supplied ephemeris file is specified by the 'CoordSys' parameter.

Any ephemeris files generated by the orbit propagator during the model runs will always use the GEI coordinate system and units. The ephemeris information, from either source, is included the model output files.

Model Output Files

The input file specifications define the types of model calculations to be performed, and the corresponding output file or files are generated. The different types of output files are distinguished by the type of data, its calculation mode, and aggregation/division.

The names of the model output files are constructed from the required 'OutFile' and 'FluxOut' parameter values, other optional model output parameter values, and any model output aggregation parameter specifications. The basic output file name assembly scheme is below. This scheme ensures unique output file names that provide descriptive information about its contents.

Prefix	Data Mode based on <*Out> value	Data Type based on <*Out> keyword	Scenario/Aggregation based on <*Agg*> keyword	Suffix
<OutFile>	_mean	_flux _fluence _dose _totaldose	(-n/a- for mean)	.txt
	_pctile		_## (percentile, in <FluxOut> value)	
	_pert _mc		_### (scenario identification #) _agg_mean _agg_median _agg_pctile_##	

Each model output file contains several header lines (comments, defined by '#' in first column) that identify the model, its parameters, type of output values, and other pertinent information (but not necessarily the complete set of model parameters). The last header line specifies the data

column labels and units. Each (CSV-format) data line contains the date/time (as Modified Julian day+fraction, see Appendix C), the GEI Cartesian coordinates (in Re), followed by one or more data values, as appropriate for the file's data type/mode/aggregation.

Tandem AE9/AP9 and Plasma Model Calculations

The 'AE9/AP9' model and 'Plasma' model (for the 'electron' and 'H+' species) may be used in tandem to provide results over a broader energy range. However, because these two models were developed independently, the results where their energy ranges overlap will not always match. When used together, it is recommend that the 'Plasma' model energy levels specified be less than 0.04MeV for electrons, and less than 0.1MeV for protons.

The 'Plasma' model differential flux values returned may be used as-is. However, to obtain *true* integral flux results, information for the energy levels that are above the 'Plasma' model energy limits needs to be included. Pseudo-integral flux Plasma model runs may be performed at the desired energies, using 'FluxType'='2PtDiff', with the 'Energies2' list values all set to 0.04MeV for electrons or 0.1MeV for protons. Integral flux 'AE9/AP9' model runs are required at 0.04MeV (and other energies, if desired) for electrons and 0.1MeV (and others) for protons, using the same ephemeris information as the Plasma runs. When all runs have been executed, use the '`IntegralPlasma.exe`' command-line application utility to perform a post-processing adjustment of the Plasma results. This rewrites the Plasma integral output files, revising the '2PtDiff' values to be 'Integral' values, incorporating the respective 'AE9/AP9' integral results at their lowest energies. More information about this utility program may be found in the accompanying '`IntPlasma_Readme.txt`' file. For user convenience, this entire post-processing adjustment operation is performed automatically within the GUI program for these types of model calculations.

Model Run Performance Tuning

When executing the model program on systems with limited amounts of free memory, the overall performance may be improved by specifying an additional parameter in the model run input file. The (optional) tuning parameter 'PtsPerCall' (default value = 240) defines the number of orbital positions being processed during each call to the lower-level model routines. The size of this processing 'chunk' directly relates to the amount of memory needed beyond the model overhead. Specifying a lower value, such as 120, should improve performance times on limited-memory systems. Lower values will also increase the frequency of progress updates.

No parallel processing capabilities are currently implemented in the model program. Separate model runs may executed simultaneously, provided an adequate amount of memory is available to support this. See the 'Epoch' parameter (in Basic Model Inputs) for related information.

Graphical User Interface Program

The GUI program provides a simple graphical user interface front-end for performing model runs with the CmdLineA9Ap9 program. Based on the selections and specifications made in the user interface, the appropriate parameter input files are generated and executed. Basic 2-D plots of the calculated model results may be produced.

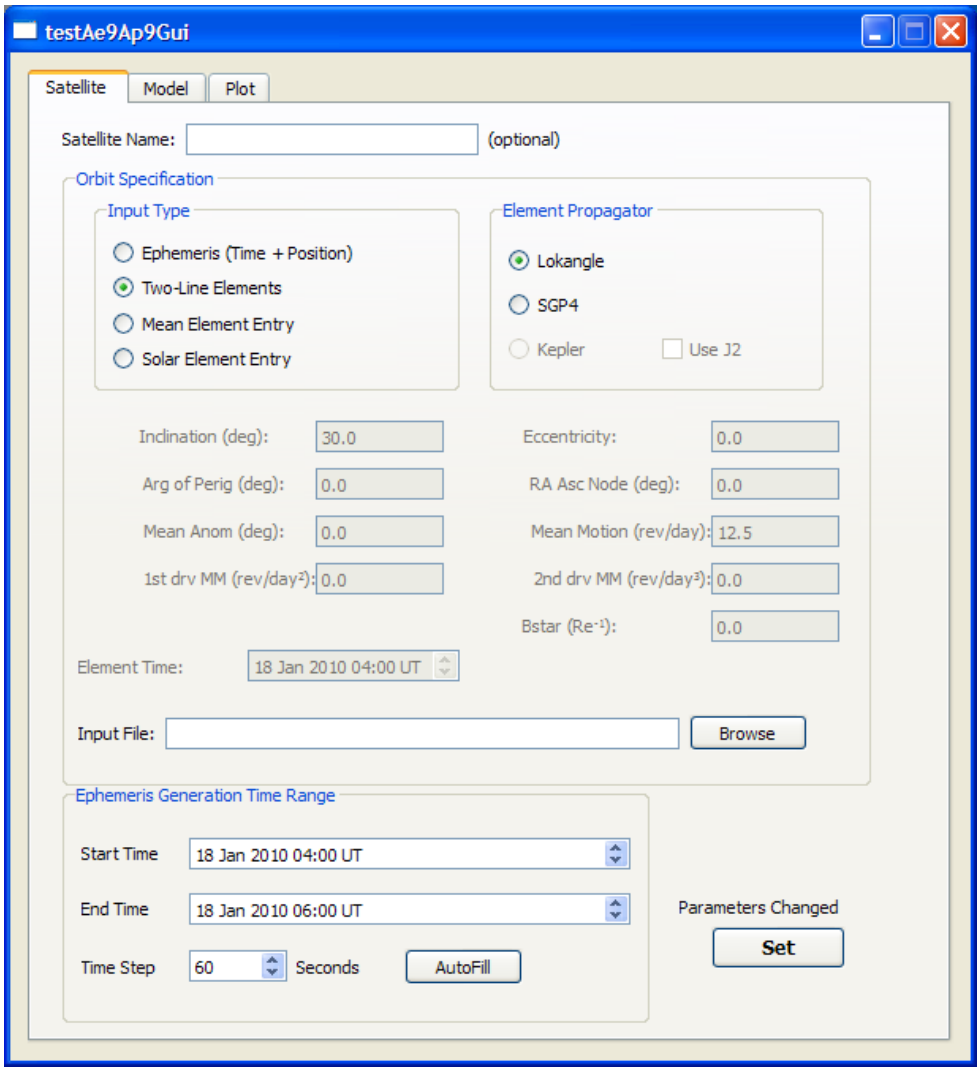
The GUI program writes files to a subdirectory (default name = "Run") of the program installation location. This directory is created if it does not exist; the user may choose another name and/or location for this directory. For each model run, the necessary input files are written in this directory, and used with the command line program. The generated ephemeris files, model run output files, and plot data files are also written to this same directory, with a user-supplied '*RunName*' prefix in their filenames.

The 'Ae9Ap9GuiDBConfig.txt' configuration file is used to identify the names and locations of the various model data base files; these are referenced in the model run input files generated by the GUI program. Use extreme caution when modifying this database configuration file, as changes made here will alter model results and/or cause model run failures. The previously-discussed model performance tuning parameter, 'PtsPerCall', may also be specified in this configuration file.

The GUI controls are divided into three tabbed pages, labeled '*Satellite*', '*Model*' and '*Plot*'. The usage and available features on each of these pages are described in the following sections.

Satellite Tab

This page collects all necessary information for defining the times and orbital positions at which the radiation environment model values are to be calculated, usually along a satellite orbital path for a specific time segment and increment.



The '*Satellite Name*' is only required when specifying custom orbital elements, and is used as part of the filename of the generated ephemeris file, in the form: '`ephem_<SatName>.dat`'. If not supplied, the default name of '`sat`' will be used.

For the orbit specification '*Input type*', select '*Ephemeris (Time+Position)*' to use an existing ephemeris file (CSV-formatted) containing a list of times and positions, in one of the supported coordinate system, as specified by the drop-down box to the right. Note that the times are expected to be in Modified Julian date plus fractional day form, and the coordinate values that follow are in the listed order, and in the specified units. See the "Supported Coordinate Systems" table, on page 10.

Model calculations at a *grid* of positions for a particular date and time may be also performed using the '*Ephemeris*' input type. However, these results at a single fixed time are unable to be plotted in the user interface '*Plot*' page, due to its limited capabilities.

The orbital path may also be defined by specifying a file containing NORAD-standard '*Two-Line Elements*' (TLE) entries, as previously discussed in the CmdLineAe9Ap9 program description section. The TLE file can contain multiple entries, but for a single vehicle only.

The use of the '*Mean Element Entry*' or '*Solar Element Entry*' selection permits their respective sets of orbital element values to be specified manually. Please note the units for each of the parameters, in particular for '*Mean Motion*'. The '*Element Time*' value associated with these orbital element values is also required.

An ephemeris file is generated (during the model run) from the specified orbital element inputs, using one of three orbit propagators, whose availability depends on the '*Input Type*' selection. The generated ephemeris positions are always in the GEI (ECI) coordinate system. The available orbit propagators are briefly described below.

- The 'Lokangle' (or 'SatEph') propagator, developed and used by researchers at AFRL for several decades. It accounts for secular and periodic perturbations, gravitational effects, and atmospheric drag. This propagator performs interpolation of the orbital elements between adjacent TLE entries.
- The 'SGP4' (Simplified General Perturbations) propagator (sometimes called SPACETRACK) considers secular and periodic variations due to Earth oblateness, solar and lunar gravitational effects, gravitational resonance effects, and orbital decay using a drag model. It uses the latest TLE entry for the given time, and may exhibit a slight discontinuity in the ephemeris position at the time of next TLE entry.
- The 'Kepler' propagator is very basic orbit propagator, without applying any perturbations, except for 'J2' effects if selected. The 'J2' perturbation accounts for secular variations in the orbit due to oblateness of the Earth. The minimal/no perturbations makes the Kepler propagator ideal for the generation of extremely long-duration ephemeris information with stable orbit characteristics. By neglecting higher-order physics, this propagator simulates the effects of station keeping maneuvers.

Both the 'SGP4' and 'Kepler' propagators are 'forward-generating' only. That is, they are unable to compute ephemeris at times prior to the specified 'Element Time', or prior to the first time value in the supplied TLE file.

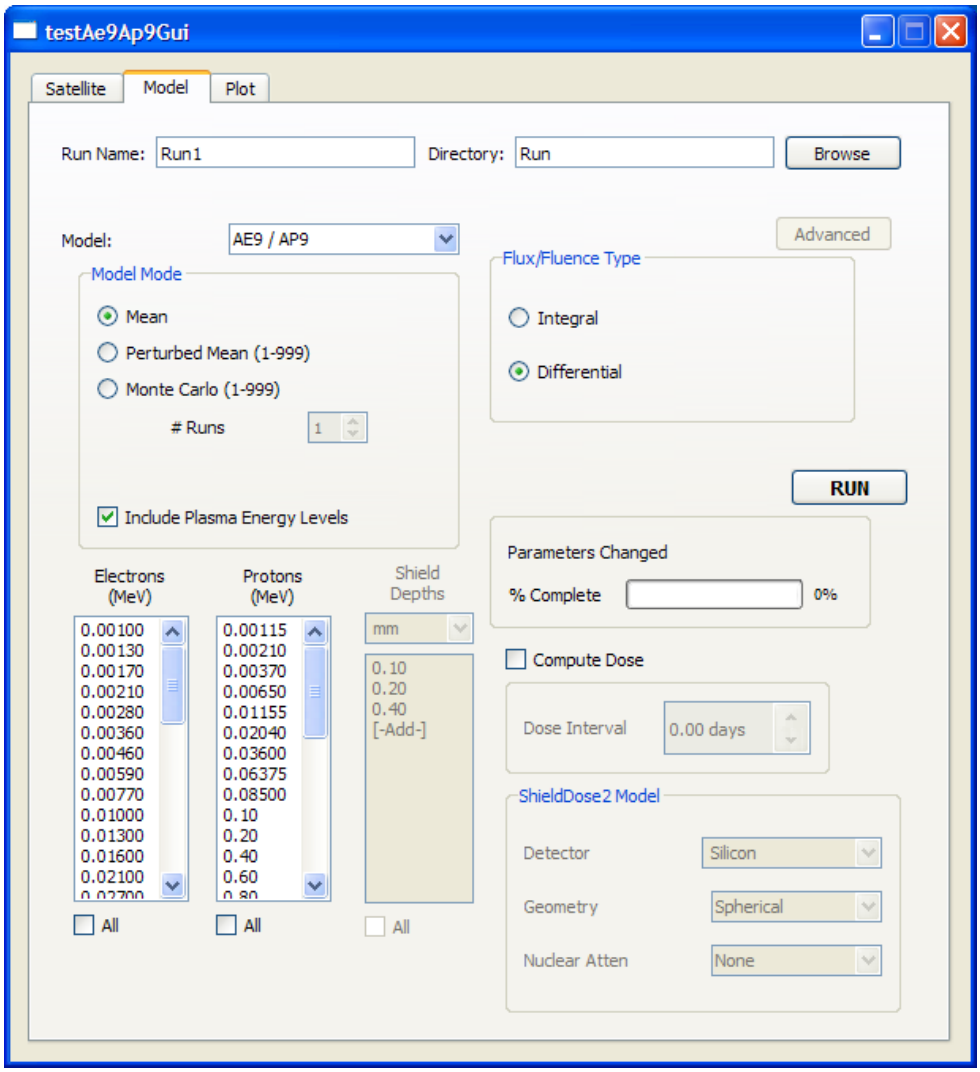
The time limits of the ephemeris file to be generated are specified by the '*Start Time*' and '*End Time*' entries, with an associated time increment. Please keep in mind that a small '*Time Step*' value will result in more time values at which the model values are being calculated. Model runs for long time periods with small time steps could potentially require many hours, days or weeks to complete, depending on your computer system performance. The recommended time step values for adequate model resolution, based on the general orbit type, are: LEO: 10 seconds; MEO: 300 seconds; HEO: 60 seconds; GEO: 3600 seconds. The optimal time step size will depend on the exact characteristics of the satellite orbit being used.

For TLE input files, the '*Autofill*' button is available – when pressed, the TLE file is scanned, and the '*Start Time*' is set to match to the first element entry time, and the '*End Time*' is set to be the last element entry time plus one day. The filename of the generated ephemeris file will be in the form: '`ephem_<`*`TLE_input_file`*`>.dat`'.

When all selections and specifications have been made, press the '*Set*' button. The various inputs are checked, ensuring valid element values and time entries. If applicable, the input file is also scanned, confirming the expected format and that its values are within their respective acceptable ranges. An informative dialog box will be displayed if any problems are detected.

Model Tab

This page collects all user-specified parameters required for calculating the various model values at the defined ephemeris positions. Each set of model run input and output files will be written in the specified '*Run*' directory, with their file names containing the prefix specified in the '*RunName*' entry.



Five models are available from the '*Model*' drop-down box – 'AE9/AP9', 'Plasma', and three "legacy" models: 'AE8/AP8', 'CRRES ELE/PRO' and 'CAMMICE/MICS'. Depending on which model is selected, the appropriate parameter selections are shown in the GUI window.

For the 'AE9/AP9', 'AE8/AP8' and 'CRRES ELE/PRO' models, dose calculations may also be performed using the calculated particle flux and fluence results. This feature is activated by checking the '*Compute Dose*' checkbox, which enables the selection of the "ShieldDose2" model parameters, and also automatically selects all energy levels of both electrons and protons. The '*Dose Interval*' value specifies the frequency (in ephemeris data time) at which the dose

calculations are performed. A value of "0.0" means the calculations are performed at every timestep, which may *significantly* lengthen the overall model execution time. A value of "0.25" (days) means the calculations are performed on the aggregation of flux values for the preceding 6 hours-worth of ephemeris positions. Additional information about the other "ShieldDose2" model parameters may be found in the previous Command-Line Program/Dose Calculation Inputs section (page 14) of this document, and [Seltzer, 1994].

The values in the '*Shield Depths*' list may be displayed in units of '*g/cm*^{2}', '*mm*' or '*mils*'. Using the drop-down box to select a different unit will automatically convert the existing entry values to the new units.

The values comprising the '*Shield Depths*' list may also be customized. Double-click on an entry to edit its value (or alternatively, use Shift+Ctrl+click). When the editing of an entry is complete, its position in the list will automatically be adjusted to maintain increasing numerical order. Entering "`0`" or blank will delete the entry. New entries may be added to the list by selecting the special '*[-Add-]*' entry at the bottom of the list. The list's pop-up "tooltip" information shows the expected range of valid values, as well as these editing instructions. These customized list values may be saved to a file by pressing 'Shift' when clicking on a list entry. A saved list of values may be reloaded by pressing 'Ctrl' when clicking on a list entry. Only valid list entries from appropriate list files will be loaded. Appropriate error, warning or informational dialogs will be displayed as needed.

AE9/AP9-specific notes:

The Electron and Proton energy lists show two distinct sets of values within each list. Those energy values with five digits to the right of the decimal point are calculated using the SPM 'Plasma' model for 'electrons' and/or 'H+'(protons). Those energy values with only two digits are calculated with the AE9/AP9 model. "Monte Carlo"-type calculations will not be available if any of the 'Plasma' energy values are selected. These energies may be removed from the list toggling the provided checkbox.

The calculation of *Integral* flux values of the 'plasma' energies will automatically invoke a calculation of the integral flux values of the AE9/AP9 at their respective lowest energy levels, if not already selected. The results produced for the plasma energy levels will be adjusted to incorporate the results of these lowest energy AE9/AP9 energies. This post-processing adjustment of the plasma results is performed automatically within the operation of the GUI. For manually-performed model runs, the '`IntegralPlasma`' utility may be used to perform this post-processing adjustment, provided that the specific set of requirements of the associated model runs are met.

The energy lists for the '`AE9/AP9`' and '`Plasma`' models only may be customized in the same manner as that of the '*Shield Depths*' list. The energy list values used with the legacy models

cannot be changed. The 'CAMMICE/MICS' legacy model always calculates results for *all* of its pre-defined energy bins.

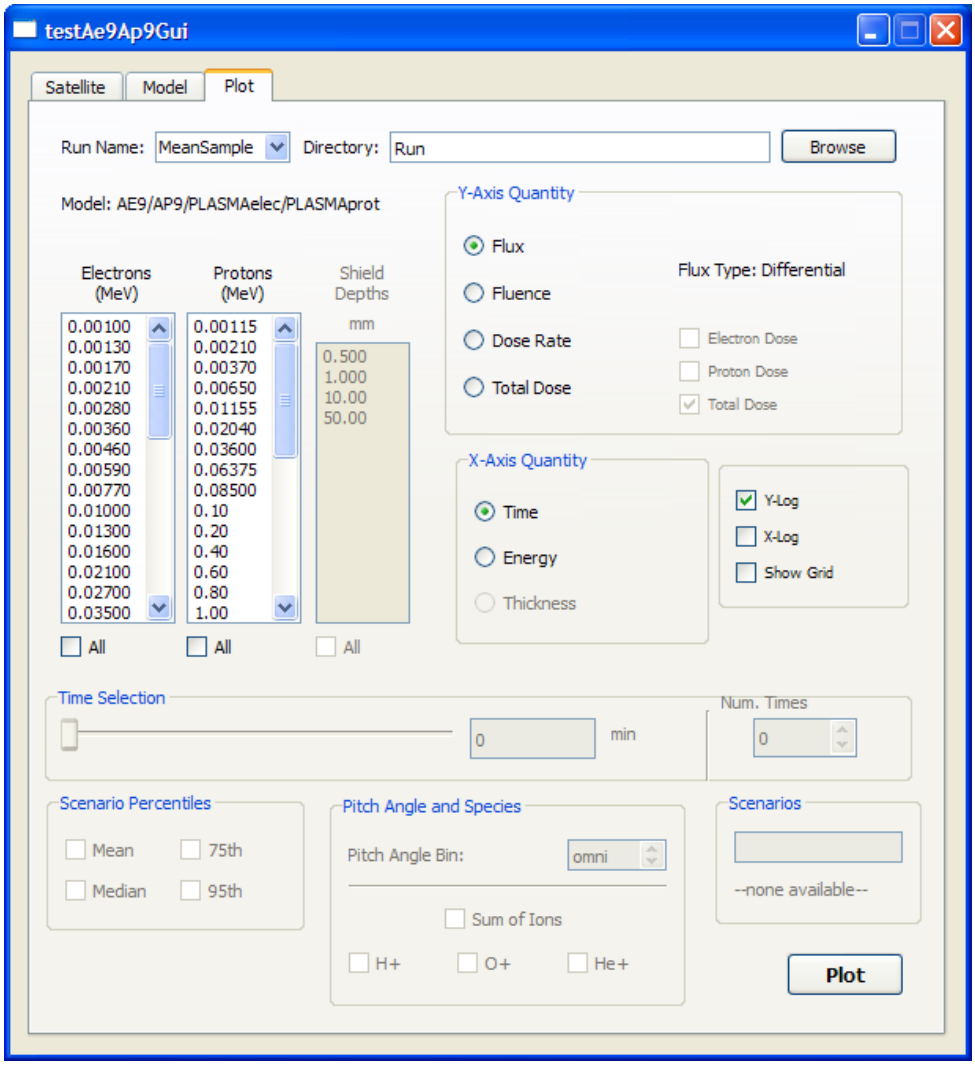
If one of the legacy 'AE8/AP8' or 'CRRES ELE/PRO' models is selected, additional parameters are available via the 'Advanced' button. A warning is displayed: un-physical results may be produced if the default 'Advanced' settings are altered. After acknowledging this warning, an extra dialog box is shown, containing two checkboxes. The "Use Native Epoch" option is checked by default, and imposes the use of model-specific year values (rather than the year specified by the satellite ephemeris) for the magnetic field model when performing the flux calculations for these legacy models. The "Translate SAA" option, unchecked by default, can be used to shift the SAA from its 'native epoch' year location to that for the current year specified in the satellite ephemeris. See [Heynderickx et al, 1996] for more details.

When all model parameters and settings have been selected, press the '*Run*' button. The various model parameter inputs are verified to contain proper and/or compatible settings. An informative error dialog is displayed if problems are detected. If the '*RunName*' specification has been used before, a dialog box will ask if the previously generated files may be overwritten. When the various selections have all been verified, a set of input files are generated, named in the form: '`<RunDir>/<RunName>.<Model>.CLinput.txt`'. These input files are supplied to the Command-Line program for the model execution. Model runs that require multiple portions to be executed (ie, Electrons and Protons), are done in a serial manner (no parallel execution is available at this time). Any required ephemeris file generation will be performed during the first portion, and the resulting file will be used as input for subsequent portions. If an error occurs during one of the model run portions, any remaining portions will not be run, and the model run files associated with '*RunName*' will be marked as "incomplete". An error dialog will notify the user if this occurs.

During the execution of the necessary model runs, the '*Run*' button will show '*-busy-*', and the run status will be shown in the '*% Complete*' progress bar. The update rate and frequency of this progress bar will vary, depending on the number of ephemeris positions being used, the model and species selected, and the types of calculations being performed. While "busy", the various satellite and model GUI selections are able to be viewed, but no changes are permitted. When the model runs have successfully completed, the button is changed back to showing 'Run'. The generated model output files are named in the form: '`<RunDir>/<RunName>.<Model>.CLoutput_<type>.txt`'. The pre-defined '`<Model>`' names are shown in the next section. The various permutations for '`<type>`' are shown in the previous Command-Line Program/Model Output Files section.

Plot Tab

This page provides a method for producing basic 2-D plots of the model calculation results.



For the specified '*Directory*' location, all available '*RunName*' model runs are shown in the drop-down list. These can be from this current or any previous GUI program session. Manually-configured and -executed model runs may also be selected, provided that the expected input and output file-naming form has been used:

Input file = "`<RunName>.<Model>.CLinput.txt`",
and containing 'OutFile' parameter = "`<RunName>.<Model>.CLoutput.txt`".

Where `<Model>` is one of : 'AE9', 'AP9', 'PLASMA_E', 'PLASMA_O', 'PLASMA_H', or 'PLASMA_HE', and/or:

- for AE9/Ap9/SPM "tandem" runs : 'PLASMAelec' and 'PLASMAprot'
- for legacy models: 'AE8', 'AP8', 'CRRESELE', 'CRRESPRO' or 'CAMMICE'.

Based on the input and output files of the selected '*RunName*', the model name and flux type are identified, and the lists for energy levels and shield depths used are appropriately populated. Other pertinent information, such as scenario collections, pitch angles and/or species are also shown. Additional details of the full set of model parameters are always available from the model run input files.

If the selected '*RunName*' has been marked as "incomplete", a warning dialog is displayed. Attempts to plot from this may show incorrect results and/or cause program instability.

The selection methods for the desired energy levels or shield depth values will depend on the type of plot desired: versus '*Time*', '*Energy*' or '*Thickness*'. The model run parameters may also dictate additional selections are needed, such as species, or scenario numbers and/or percentiles.

For plots of values versus '*Energy*' or '*Thickness*', two time-slice specification methods are available. The '*Time Selection*' slider allows a specific time value within the dataset to be selected. Alternatively, when the '*Num Times*' spinbox is changed from zero, this specifies the number of evenly-spaced time slices to plot, the first one always at time "t=0" of the time period.

Press the '*Plot*' button when selections are complete. An informative error dialog is displayed if additional selections are required. The plot is displayed in a new window; the GUI will remain frozen until this plot window is closed. However, if the selected model results are all zeros, no plot will be produced and a notice is displayed.

Based on the selections made, one or more sets of data values are plotted, each using a different color and/or dot/dash pattern. The key below identifies each of these lines. Dose values are plotted based on their '*Dose Interval*' specification, and so these graphs versus time may appear as steps rather than curves if a non-zero interval is used.

For each plot produced, a CSV-formatted file of the data plotted is written in the same directory. These files are suitable for use by other plotting programs. The file-naming form is: '`<RunName>_Plot_<###>.txt`', where '`###`' is simply the number of the plot generated *during the current GUI program session*. Parameter labels for each data column are included in these plot data files, but do not provide model run parameters. These details are always available in the associated '*RunName*'-prefix model input files.

Example GUI-based Model Runs

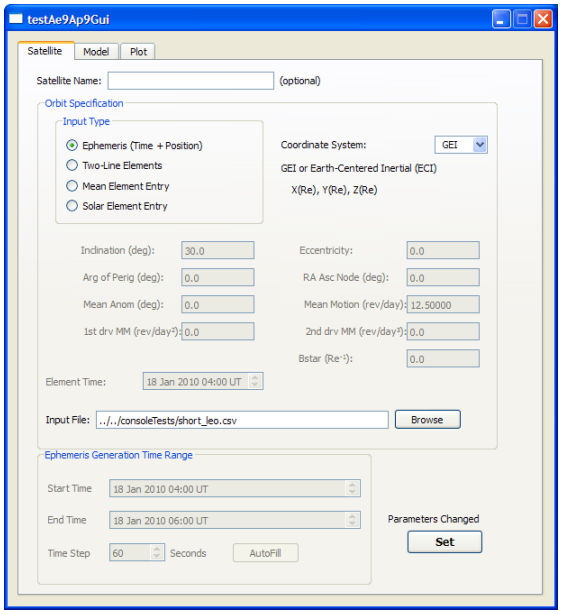
Several examples of using the GUI to perform model runs and produce basic plots are shown in the series of screenshots below.

Approved for public release; distribution is unlimited.

Example 1: MeanSample

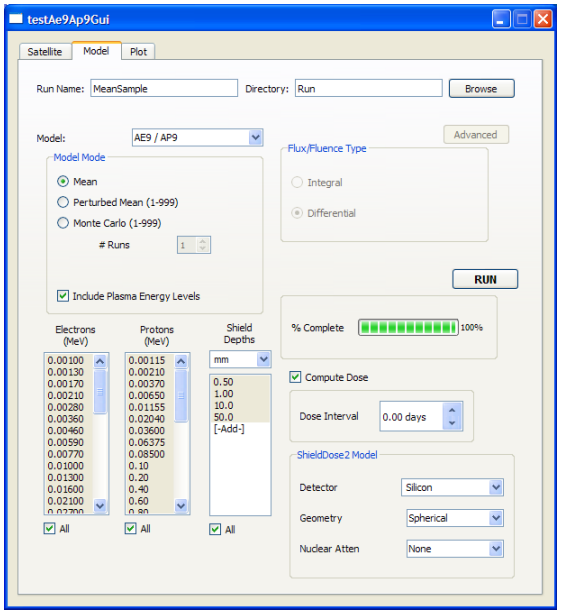
Satellite Tab:

-Select ‘Ephemeris’
-Enter ‘short_leo.csv’ for Input File
-Press ‘Set’



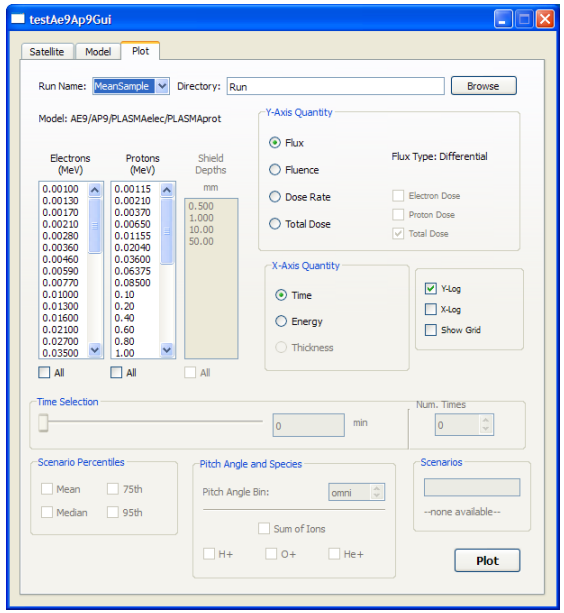
Model Tab:

-Enter ‘MeanSample’ for Run Name
-Select a directory for files
-Check ‘Compute Dose’ checkbox
(all electron and proton energies will automatically be selected)
-Double-click on the first four lines in the ‘Shield Depths’ list, entering the values of 0.50, 1.0, 10.0 and 50.0 (units = ‘mm’)
-Check the ‘All’ checkbox below the Shield Depths list
-Press ‘Run’
-The progress bar will show the run completion status.



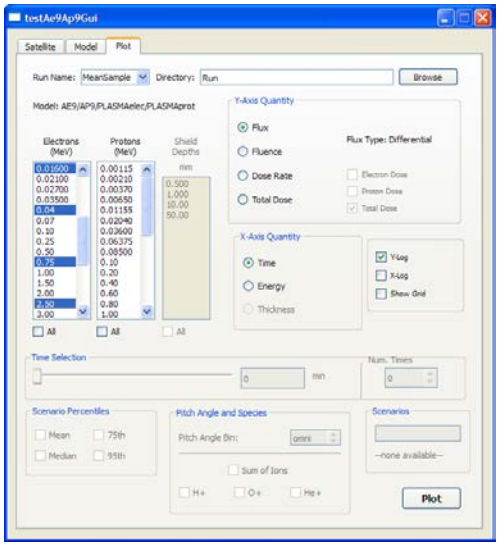
Plot Tab:

At the conclusion of the model run, switch to the ‘Plot’ tab; the Run Name will automatically be set to the ‘MeanSample’ name. The electron and proton energy levels and shield depths, as selected on the Model tab, will populate their respective lists on the Plot tab.



MeanSample, Continued (Plot Tab)

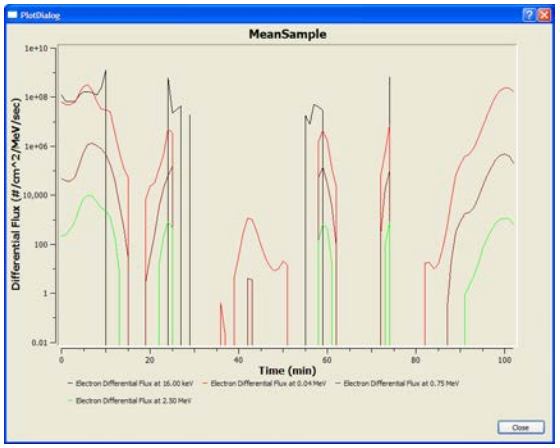
-Select a few electron energy levels
-Press ‘Plot’



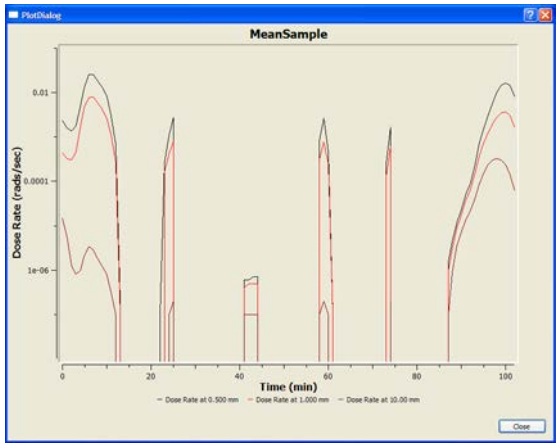
A pop-up window containing the graph will appear.

This user interface provides the ability to generate many different types of 2D plots from the available model run output data files, such as:

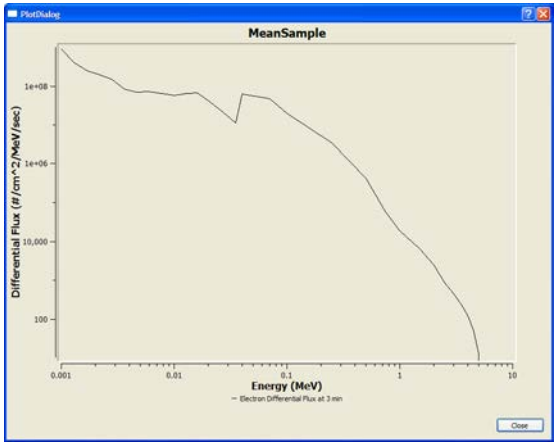
→Flux or Fluence vs Time



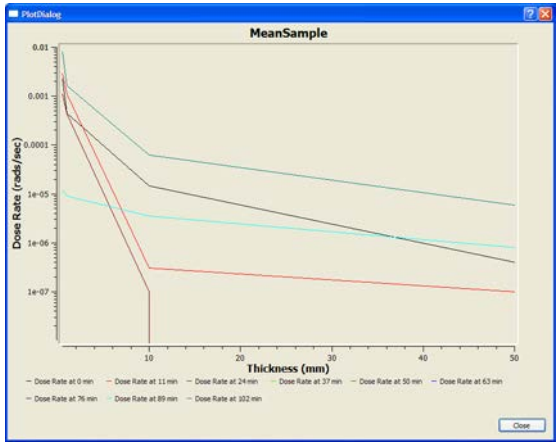
→Dose Rate or Total Dose vs Time



→Flux or Fluence vs Energy,
at a single time, or multiple times



→Dose Rate or Total Dose vs Thickness
at a single time, or multiple times



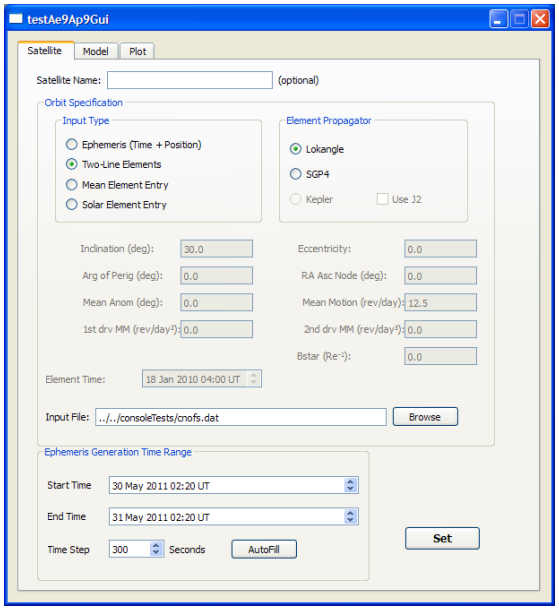
Approved for public release; distribution is unlimited.

Approved for public release; distribution is unlimited.

Example 2: MonteCarloSample

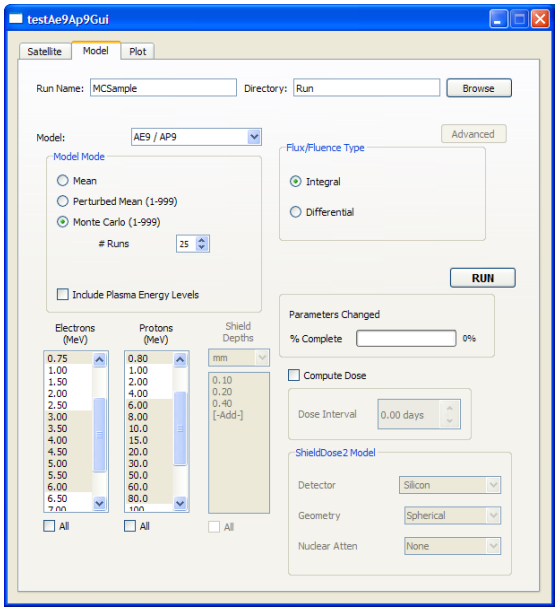
Satellite Tab:

-Select ‘Two-Line Elements’ input type
-Select ‘Lokangle’ propagator
-Enter ‘cnofs_tle.dat’ for Input File
-Press ‘Autofill’
-Set TimeStep to be 300 seconds
-Press ‘Set’



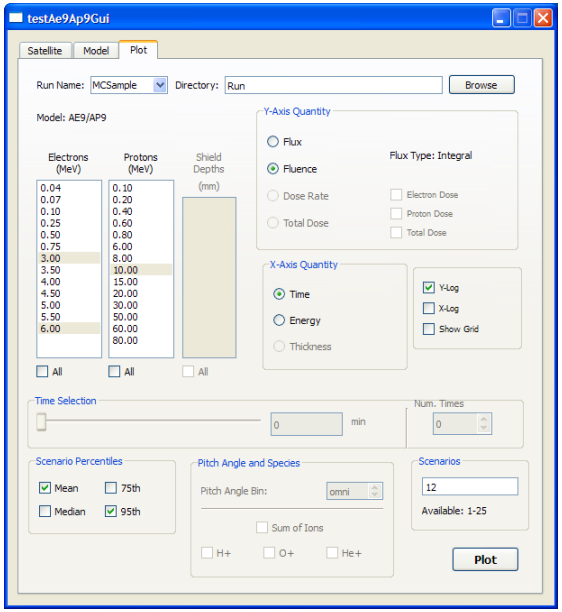
Model Tab:

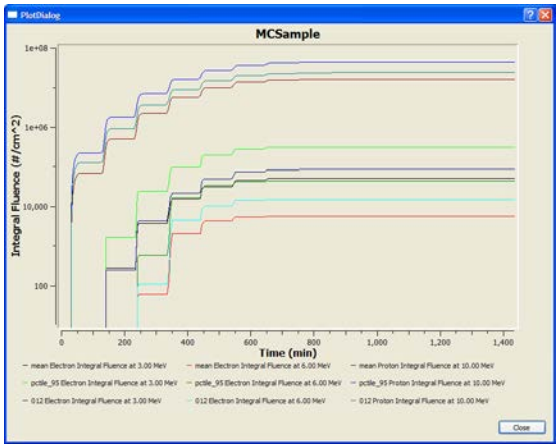
-Enter MCSample for Run Name
-Select ‘Monte Carlo’ as Model Mode
-Set ‘# Runs’ to “25”
-Select ‘Integral’ as Flux/Fluence Type
-Uncheck ‘Include Plasma Energy Levels’ checkbox
-Select electron energies 0.04 – 0.75 and 3.0 – 6.0
-Select proton energies 0.1 – 0.80 and 6.0 – 80.0
-Press ‘Run’, wait for run completion.



Plot Tab:

-Select ‘Fluence’
-Select Electron energies 3.0 and 6.0, and Proton energy 10.0
-Check ‘Mean’ and ‘95th’ percentiles
-Enter ‘12’ in Scenarios
-Press ‘Plot’



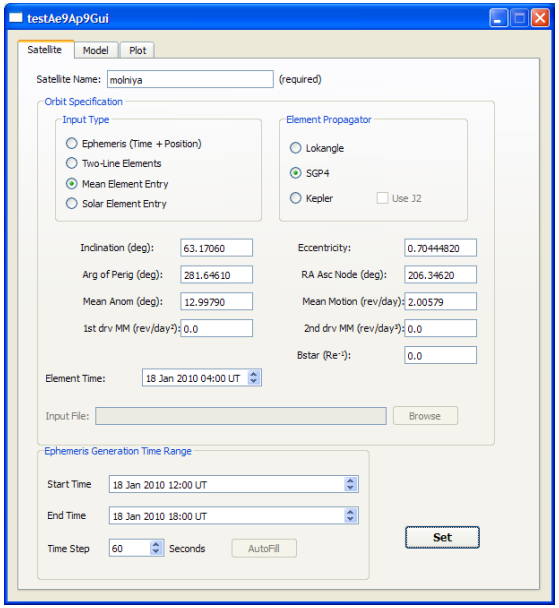


Approved for public release; distribution is unlimited.

Example 3: PerturbedMeanSample

Satellite Tab:

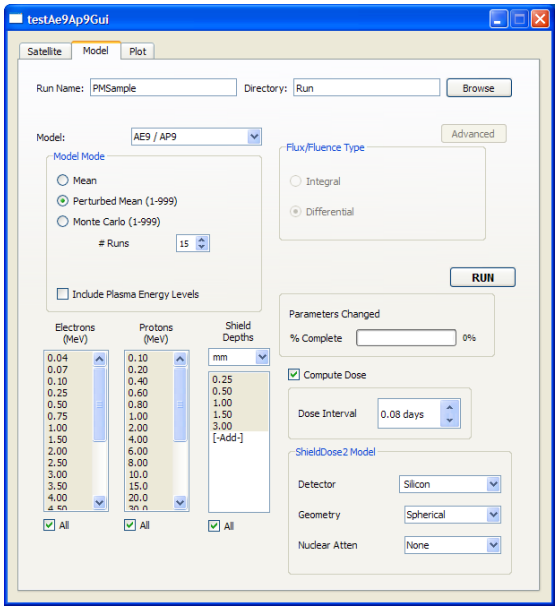
-Select ‘Mean Element Entry’
-Select ‘SGP4’ propagator
-Enter element values, time limits and time step value, as shown below
-Press ‘Set’



Model Tab:

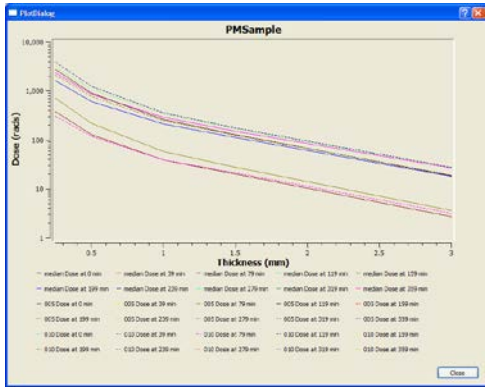
-Enter ‘PMSample’ for Run Name
-Select ‘Perturbed Mean’, with #Runs=15
-Uncheck ‘Include Plasma Energy Levels’
-Check ‘Compute Dose’ checkbox

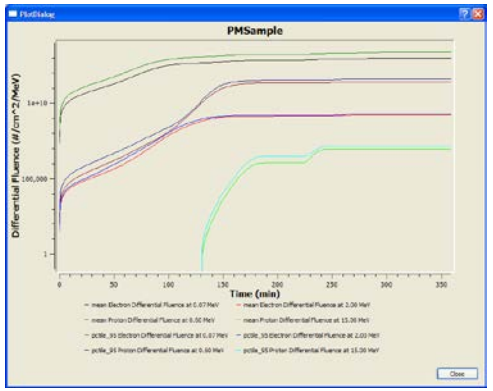
(all electron and proton energies will automatically be selected)
-Enter Shield Depths of 0.25, 0.50, 1.0, 1.50 and 3.00
-Check 'All' under Shield Depths
-Select a 0.08 day dose interval
-Press ‘Run’

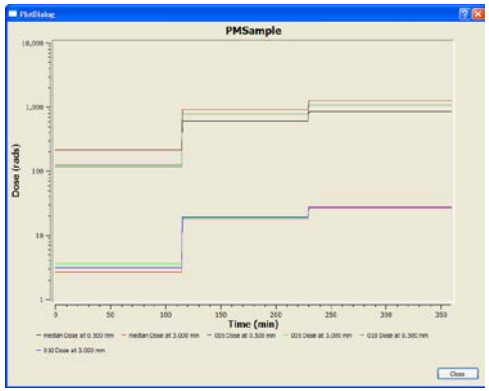


Plot Tab:

-Many types of plots are available
-Selections can be determined from each plot’s labels and legends







References:

Bhavnani, K.H., and R.P. Vancour, "Coordinate systems for space and geophysical applications," PL-TR-91-2296, Phillips Laboratory, Hanscom AFB, MA, [http://www.dtic.mil/dtic/tr/fulltext/u2/a247550.pdf], 11 Dec. 1991.

Ginet, G.P., T.P. O'Brien, S.L. Huston, W.R. Johnston, T.B. Guild, R. Friedel, C.D. Lindstrom, C.J. Roth, P. Whelan, R.A. Quinn, D. Madden, S. Morley, and Yi-Jiun Su, "AE9, AP9 and SPM: New Models for Specifying the Trapped Energetic Particle and Space Plasma Environment," Space Science Reviews, [http://dx.doi.org/10.1007/s11214-013-9964-y], March 2013.

Seltzer, Stephen M., "Updated Calculations for Routine Space-Shielding Radiation Dose Estimates: SHIELDOSE-2," National Institute of Standards and Technology Publication NISTIR 5477, 1994.

Heynderickx, D., J. Lemaire, E.J. Daly, and H.D.R. Evans, "Calculating Low-Altitude Trapped Particle Fluxes with the NASA Models AP-8 and AE-8," Radiation Measurements, Vol. 26, pp. 947-952, 1996.

Heynderickx, D., private communication, May 2013.

Appendix A: Legacy Models AE8/AP8 and CRRESELE/PRO-specific parameters

These legacy model parameters are to be used along with the standard orbital specification parameters, and optionally with the Dose calculation parameters.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
ModelType	AE8, AP8, CRRESELE, CRRESPRO	Required	none	Type of model to be run
ModelDB	<path>/radiationBeltDB.h5	Required	none	Database file used to drive the model. Must include path to file (absolute, or relative to CmdLineAe9Ap9 location).
OutData	Flux, Fluence, DoseRate, CumDose	Required	none	Model value for output. This parameter may appear multiple times.
FluxType	1PtDiff, Integral	Required	none	Type of flux values to be computed.
Energies	AE8: 0.04 – 8.0 AP8: 0.1 – 250.0 CRRESELE: 0.65, 0.95, 1.60, 2.0, 2.35, 2.75, 3.15, 3.75, 4.55, 5.75 CRRESPRO: 1.5, 2.1, 2.5, 2.9, 3.6, 4.3, 5.7, 6.8, 8.5, 9.7, 10.7, 13.2, 16.9, 19.4, 26.3, 30.9, 36.3, 41.1, 47.0, 55.0, 65.7, 81.3	Required	none	Comma-separated list of energy levels, in MeV, at which flux values are to be computed, at each time step. Energy values for AE8 or AP8 are restricted to their model-specific ranges. For the CRRES models, only these specific energy levels (or a subset) may be used.

Approved for public release; distribution is unlimited.

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
REActLvl	AE8 or AP8: 'min', 'max' CRRESPRO: 'active', 'quiet'	Required*	none	Activity Level (*except for CRRESELE)
REActRange	'5-7.5', '7.5-10', '10-15', '15-20', '20-25', '>25', 'avg', 'max', or 'all'	Crresele*	none	Activity Level for CRRESELE *this or 'RE15DayAP' parameter is required
RE15DayAP	0.0 – 400.0	Crresele*	none	15 day average AP index for CRRESELE *this or 'REActRange' parameter is required
REFixEpoch	True , False	Optional	true	Use the model-specific fixed epoch (year) values for the magnetic field model in the flux calculations. It is *highly recommended* to use the default 'true' value. Un-physical flux results may be produced (especially at low altitudes) if set to 'false'. See [Heynderickx et al, 1996], for more information.
REShiftSAA	True, False	Optional	false	Shift the SAA from its fixed-epoch location to the location for the current year of the ephemeris. See [Heynderickx et al, 1996], for more information. This option is ignored if REFixEpoch is 'false'.

Approved for public release; distribution is unlimited.

Appendix B: Legacy Model CAMMICE/MICS-specific parameters

These CAMMICE/MICS model parameters are to be used along with the standard orbital specification parameters. No energy level specifications are needed – values are always output for the twelve pre-defined energy bins (1.0-1.3, 1.8-2.4, 3.2-4.2, 5.6-7.4, 9.9-13.2, 17.5-23.3, 30.9-41.1, 54.7-72.8, 80.3-89.7, 100.1-111.7, 124.7-139.1, 155.3-193.4 keV). Dose calculation parameters may also be specified for the CAMMICE/MICS model, but will generally produce non-zero dose results only for the top three energy bins (>0.1MeV).

Parameter Keyword Name	Allowed Values	Required	Default Value	Description
ModelType	CAMMICE	Required	none	Type of model to be run (requires corresponding database file specified in ModelDB parameter)
ModelDB	<path>/cammiceDB.h5	Required	none	Database file used to drive the model, corresponding to the selected ModelType. Must include path to file (absolute, or relative to CmdLineAe9Ap9 location).
FluxType	1PtDiff, Integral	Required	none	Type of flux values to be computed.
CIModel	igrf, igrfop	Required	none	Magnetic field model to use with CAMMICE (igrfop = IGRF w/ Olson Pfitzer external field model)
CIDstData	all, filtered	Required	none	CAMMICE data filter: use all data, or data for DST > -100
CISpecies	h+, he+, he+2, o+, h, he, o, ions	Required	none	CAMMICE species for which to return flux data. This parameter may appear multiple times.
CIPAngle	'0-10', '10-20', '20-30', '30-40', '40-50', '50-60', '60-70', '70-80', '80-90', '90-100', '100-110', '110-120', '120-130', '130-140', '140-150', '150-160', '160-170', '170-180', or 'omni'	Required	none	Bin of pitch angles for which to return flux data in CAMMICE (omni=omnidirectional)

Approved for public release; distribution is unlimited.

Appendix C: Modified Julian Date

The Modified Julian Date (MJD) is an astronomical time convention that has the great advantage of being a continuous time variable, without the discontinuities introduced by the usual civil time convention of years, month, days, hours, minutes and seconds. This makes it ideal for computer manipulation of long time series.

The Modified Julian Date is derived from a much older system called 'Julian Date', which was defined as the time, in days, since *noon* (1200GMT) on 1 January 4713 BC. The MJD simply subtracts 2400000.5 from the Julian Date (the extra 0.5 shifts the start of days from middle to the beginning). Thus, the use of MJD requires only use of 5 (rather than 7) digits to the left of the decimal point. It is defined as days since 17 Nov 1858, 0000GMT.

For example

01 Jan 2000, 1200GMT is Julian Date 2451545.0, and Modified Julian Date 51544.5
10 Oct 2012, 0000GMT is Julian Date 2456210.5, and Modified Julian Date 56210.0
01 Jan 1950, 0000GMT is Julian Date 2433282.5, and Modified Julian Date 33282.0

Many tools and algorithms exists to convert between calendar date and time to Julian or Modified Julian Dates

http://www.onlineconversion.com/julian_date.htm
http://scienceworld.wolfram.com/astronomy/ModifiedJulianDate.html
http://www.csgnetwork.com/julianmodifdateconv.html

In Excel, if you have a date/time in cell A1, then the following formula will convert it to MJD (but you'll need to set the formula's cell format to "number")"

```
=A1-date(1950,1,1)+33282
```

This works because Excel uses a date serial that is a decimal number of days since some reference epoch.

Matlab also uses some reference epoch. This snippet of Matlab code will convert a date string to MJD:

```
mjd = datenum(date_string)+33282-datenum(1950,1,1);
```

An important warning for users of SPENVIS – a *NON-STANDARD* definition for 'Modified Julian Date' is used:
"Finally, note that the Modified Julian Date (MJD) used in SPENVIS is defined as the number of days from 1st January 1950 00:00 UT."
see http://www.spenvis.oma.be/help/models/sapre.html

Approved for public release; distribution is unlimited.

DISTRIBUTION LIST

DTIC/OCP
8725 John J. Kingman Rd, Suite 0944
Ft Belvoir, VA 22060-6218 1 cy

AFRL/RVIL
Kirtland AFB, NM 87117-5776 2 cys

Official Record Copy
AFRL/RVBXR/Dr. Michael Starks 1 cy